PRELIMINARY ESTIMATES OF THE ANNUAL NUMBER OF SETS, NUMBER OF DOLPHINS CHASED, AND NUMBER OF DOLPHINS CAPTURED BY STOCK IN THE TUNA PURSE-FISHERY IN THE EASTERN TROPICAL PACIFIC, 1971-2000

F. Archer, T. Gerrodette, and A. Jackson

Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
8604 La Jolla Shores Drive
La Jolla, California 92037

JUNE 2002

Preliminary estimates of the annual number of sets, number of dolphins chased, and number of dolphins captured by stock in the tuna purse-seine fishery in the eastern tropical Pacific, 1971-2000

F. Archer, T. Gerrodette, A. Jackson
Southwest Fisheries Science Center

ABSTRACT

Although the total number of sets on all species of dolphins has been reported annually in the tuna purse-seine fishery in the eastern tropical Pacific, the number of sets on each dolphin stock has not previously been estimated. Here we report preliminary estimates of the number of sets (1971-2000), the number of dolphins chased (1975-2000), and the number of dolphins captured (encircled) in purse-seine nets (1977-2000) each year during the periods indicated for nine dolphin stocks involved in the fishery. Northeastern offshore spotted dolphins were the stock most frequently set on, being involved about 60% of all dolphin sets, or approximately 4,000-6,000 sets/year in recent years. Western/southern offshore spotted dolphins and eastern spinners dolphins were approximately equal in the number of sets, with each occurring in 25%-30% of all dolphin sets, followed by whitebelly spinners with about 20% (the sum is > 100% because of mixed-species schools). All other stocks were present in fewer than 5% of the sets each on average. From 1990 to 2000, the number of northeastern offshore spotted dolphins captured (encircled in the purse-seine net) ranged from 1.5 to 3.5 million animals/year, and the number of dolphins chased (whether the chase ended in a capture or not) ranged from 4.6 to 8.2 million animals/year. For eastern spinner dolphins, the same numbers were 0.27 to 0.48 million dolphins captured/year and 1.7 to 2.9 million dolphins chased/year. On a per capita basis over the same time period, the mean rates were 3.5 captures/year and 10.2 chases/year for northeastern offshore spotted dolphins, and 0.8 captures/year and 5.0 chases/year for eastern spinner dolphins. Eastern spinner dolphins either evaded the net or were deliberately cut out of the school before the net was set at a higher rate than northeastern offshore spotted dolphins.

INTRODUCTION

Under the International Dolphin Conservation Program Act (IDCPA), the National Marine Fisheries Service (NMFS) was required to determine "whether the intentional deployment on or encirclement of dolphins with purse seine nets is having a significant adverse impact on any depleted dolphin stock in the eastern tropical Pacific Ocean" (16 United States Code 1385). In order to fulfill this mandate and evaluate the effect of the fishery, it is essential to estimate how often purse-seine operations take place on each dolphin stock. The Inter-American Tropical Tuna Commission (IATTC) publishes an Annual Report that lists the number of dolphin sets made each year in the eastern tropical Pacific yellowfin tuna fishery (IATTC 2002). However, this information is not reported for each dolphin stock separately. Additionally, with the exception of Perkins and Edwards (1998), who estimated the number of northeastern offshore spotted dolphins "captured" (actually chased and/or captured – see distinction below) in the 1986-1990 period, there are no published estimates of the number of dolphins in each stock chased

and captured yearly. Therefore, the goal of this analysis was, for each dolphin stock involved in the tuna fishery, to provide annual estimates of the number of sets made, the number of dolphins chased, and the number of dolphins captured, plus additional related statistics.

In the process of catching tuna by setting on dolphins, speedboats chase and herd the tunas and dolphins into a tight aggregation so that the seine can be set around them. During the chase, fishermen may attempt to "cut out" parts of the dolphin school not associated with tuna. Therefore, some dolphins are chased for varying lengths of time but do not experience capture (encirclement in the purse seine). In addition, not all chases result in sets. Chases may be aborted for a variety of reasons, including insufficient fish and adverse weather conditions. Thus, the number of dolphins chased is larger than the number captured each year. Chasing and capturing represent different kinds of interactions with the fishery, and we estimate the number of dolphins experiencing these effects separately.

METHODS

General

We used data extracted from NMFS and IATTC set-log and sighting databases. The NMFS data came from observers placed aboard U.S.-registered vessels from 1971 to 1990. IATTC has placed observers aboard vessels of various countries since 1979. We used IATTC data from 1986, which was the first year all fishing countries participated in the observer program, through 2000. Thus, there was a five-year period of overlap between the two datasets from 1986 to 1990. From 1990 to 1995 93 trips were monitored by NMFS observers, but recorded on IATTC data sheets and stored in the IATTC database. In this study, we refer data from these trips as IATTC data. Unless otherwise stated, NMFS and IATTC data were analyzed separately.

We refer to the NMFS and IATTC data for which we had by-stock information as "observed" data, and we treat these observed data as samples on which to base our estimates. There were three situations in which fishing trips were not included in the observed data: (1) trips with no observer aboard; (2) trips with an observer who was part of a national observer program other than the U.S.; and (3) trips made with an IATTC observer prior to 1986. Although we either did not have or did not request by-stock data in these cases, the total number of sets made on dolphins each year is known or estimated (IATTC 1999, 2002) (Table 1). With the institution of national and international observer programs and an increase in observer coverage, the fraction of sets for which we have by-stock data has increased from 1% in 1971 to approximately 70% in recent years (Figure 1). [1]

We considered nine dolphin stocks that are taken in the fishery, following the stock definitions in Dizon et al. (1994): coastal, northeastern offshore, and western/southern offshore spotted dolphins; eastern, whitebelly and Central American spinner dolphins; and northern, central and southern common dolphins (Table 2). We placed occurrences of any other identifiable cetacean into a separate category designated as "other." The stocks that were designated as depleted under the Marine Mammal Protection Act of 1972 are the coastal spotted dolphin (*Stenella attenuata graffmani*), the northeastern offshore

---

[1] Total coverage currently by both international and national observers is 100% (IATTC, 2002)

spotted dolphin (*Stenella attenuata attenuata*), and the eastern spinner dolphin (*Stenella longirostris orientalis*). In recent years (1996 – 2000) the latter two stocks have been involved in approximately 60% and 27% of dolphin sets respectively.

Proration of unidentified stocks

In approximately 1% of the sets, dolphins were not identified to stock. Three unidentified categories were relevant to this paper: unidentified spotted, unidentified spinner, and unidentified dolphins. Unidentified spotted dolphins were allocated to either coastal, northeastern offshore, or western-southern offshore spotted dolphins. A preliminary analysis of the by-set NMFS data (1971 – 1990) indicated that unidentified spotted dolphins were most commonly in sets by themselves or schooling with eastern spinners, which frequently occur with offshore spotted dolphins and rarely with coastal spotters. As this matches the known relative rates of mixed schooling for these stocks, we allocated all unidentified spotted dolphins based on the simple ratios of the three identified stocks of spotted dolphins.

For unidentified spinner and unidentified dolphins, the situation was slightly different. In only 1.5% and 5.7% of the sets on these two stocks were they the only stock present. Therefore, we used a different scheme to allocate these sets based on the following assumptions: 1) in a given set, an unidentified stock would not be recorded as such if it was truly the same as the identified stock it was recorded with, and 2) a stock listed as unidentified was, in reality, always a single stock and not two or more stocks.

Starting with the first assumption, we first calculated the number of sets on unidentified stocks that should not be allocated to a given identified stock ($Unot_i$) as,

$$Unot_i = nu \times \frac{n_i}{Ntotal},$$

where nu is the number of sets on unidentified stocks, i is an identified stock, n_i is the number of sets on that stock, and $Ntotal$ is the total number of sets made in that year. The number of sets on an unidentified stock that that will be allocated to each identified stock (U_i) is then,

$$U_i = \sum_{j,j \neq i} \left(Unot_j \times \frac{n_i}{\left(\sum_k n_k\right) - n_j} \right),$$

where i, j, and k are identified stocks. For each stock, i, the above equation allocates each non-i value of $Unot_j$ to all stocks but i, based on their new relative proportions (sequentially excluding each j), and sums the portion that gets allocated to i.

Using this second method, we first allocated unidentified spinners to eastern, whitebelly, or Central American spinners. We then allocated unidentified dolphins to all stocks listed in Table 2.

For allocations of unidentified stocks in the analyses of number of dolphins captured and chased, unidentified spotted dolphins were allocated based on simple ratios of identified spotted dolphins. Unidentified spinners and unidentified dolphins were allocated using the equations described above where n_i becomes the number of dolphins chased or captured in a given stock, and $Ntotal$ becomes the sum of dolphins chased or captured in the group of identified stocks to which nu (the number of unidentified dolphins) is being allocated.

5

Number of sets

The NMFS set-log database provided the total number of observed dolphin sets and the number of sets made on each stock for each year from 1971 to 1990. Identification of the stocks involved in a set was obtained from the sighting record corresponding to that set. The IATTC data provided the total number of observed sets on each stock from 1986 to 2000. For this dataset, a stock was considered set-on if that stock appeared in the observer's best estimate of the entire school composition from the IATTC set-log database. We note that, using this definition, if a stock was present at the beginning of a chase but all dolphins of that stock either evaded the set or were cut out during the chase, the set would be improperly recorded as occurring on that stock. We estimated $Nset_i$, the number of sets on stock i in each year, as

$$Nset_i = N_{sets} \left(\frac{nset_i}{nset_{total}} \right),$$

where N_{sets} was the total number of dolphin sets (second column in Table 1), $nset_i$ the observed number of sets on stock i (including the prorated sets), and $nset_{total}$ the total number of observed sets. For the period of 1986-1990, the fractions $nset_i/nset_{total}$ were calculated by adding the number of NMFS and IATTC observed sets on each stock and dividing that value by the total number of NMFS and IATTC observed dolphin sets. Note that $\Sigma nset_i > nset_{total}$ because some schools contained more than one stock.

Using the by-set data available for 1971-1990 (NMFS) and 1996-2000 (IATTC), we estimated the variance of $Nset_i$ as

$$\mathrm{var}(Nset_i) = \left(\frac{N_{sets}}{nset_{total}} \right)^2 \mathrm{var}(nset_i),$$

considering N_{sets} and $nset_{total}$ to be fixed and estimating var($nset_i$) from 1000 bootstrap samples by set. Bootstrapping was possible only for data for which we had by-set information: NMFS data for all years, and IATTC data from 1996-2000.

Number of dolphins captured

NMFS data for the number of dolphins captured for each stock annually was available from 1977 to 1990. IATTC data was available for 1986 to 2000. The number captured was taken as the observer's capture estimate of the number of dolphins in the net between the time the net skiff had tied up to the seiner and the time backdown began multiplied by the observer's estimate of the proportion of each stock in the net. If one or both of these estimates was not available for a particular set, the data for that set were not used. We estimated $Ncap_i$, the number of dolphins of stock i captured in each year, as

$$Ncap_i = N_{sets} \left(\frac{ncap_i}{nset_{total}} \right),$$

where $ncap_i$ was the observed number of captured dolphins for stock i (including the prorated sets), and N_{sets} and $nset_{total}$ were as defined above. As before, for the period of 1986-1990 the fractions $ncap_i/nset_{total}$ were calculated by adding the number of captured dolphins for NMFS and IATTC observed sets on each stock and dividing that value by the total number of NMFS and IATTC observed dolphin sets. We estimated the variance of $Ncap_i$ as

$$\mathrm{var}(Ncap_i) = \left(\frac{N_{sets}}{nset_{total}}\right)^2 \mathrm{var}(ncap_i),$$

where var(*ncap_i*) was estimated from 1000 bootstrap samples by set.

Number of dolphins chased

The number of dolphins chased is larger than the number of dolphins captured because (1) some dolphins split off from the school during the chase, and (2) some chases do not result in sets. Data were recorded somewhat differently for these two scenarios. For the set data, a chase was considered to occur if there was an entry for the time that speedboats entered the water in the set-log database. School size estimates for these chases were extracted from the corresponding sighting record. For the NMFS data, a chase was considered aborted if the Fishing Mode Record indicated a chase had started but did not have an associated set number. School size estimates for these chases were extracted from the sighting record that most closely corresponded to the time and position of the chase from the Fishing Mode Record. For IATTC data, aborted chases were recorded as such directly in the sighting record.

We estimated *Nchase.with.set_i*, the number of dolphins of stock *i* chased and set-on in each year, as

$$Nchase.with.set_i = N_{sets}\left(\frac{nchase.with.set_i}{nset_{total}}\right),$$

where *nchase.with.set_i* was the observed number of chased dolphins for stock *i* (including the prorated sets) resulting in sets, and N_{sets} and $nset_{total}$ were as defined above. For each stock, we defined the number of dolphins chased as the product of the observer's best estimate of the entire school size and the observer's estimate of the proportion of the stock in the school taken from the sighting record. NMFS data was available from 1971-1990 for chases with sets. IATTC data was available from 1986-2000. As before, for the period of 1986-1990 the fractions *nchase.with.set_i/nset_{total}* were calculated by adding the number of dolphins chased and set-on for NMFS and IATTC observed sets on each stock and dividing that value by the total number of NMFS and IATTC observed dolphin sets. We estimated the variance of *Nchase.with.set_i* as

$$\mathrm{var}(Nchase.with.set_i) = \left(\frac{N_{sets}}{nset_{total}}\right)^2 \mathrm{var}(nchase.with.set_i),$$

estimating var(*nchase.with.set_i*) from 1000 bootstrap samples.

We estimated *Nchase.without.set_i*, the number of dolphins of stock *i* chased, but not set-on in each year, as

$$Nchase.without.set_i = N_{sets}\left(\frac{nchase.without.set_i}{nset_{total}}\right),$$

where *nchase.without.set_i* was the observed number of chased dolphins for stock *i* (including the prorated sets) where a chase was started but did not result in a set, and N_{sets} and $nset_{total}$ was as defined above. NMFS data was available for 1975-1990, and IATTC data was available for 1986-2000. As previously, for the period of 1986-1990 the fractions *nchase.without.set_i/nset_{total}* were calculated by adding the number of dolphins chased in aborted NMFS and IATTC observed chases on each stock and dividing that value by the total number of NMFS and IATTC observed dolphin sets. Variance for

7

Nchase.without.set$_i$ was not estimated as we did not have the necessary detailed data on chases that did not result in sets. The total number of dolphins of stock *i* chased (*Nchase$_i$*) was the sum of *Nchase.with.set$_i$* and *Nchase.without.set$_i$*.

We estimated the fraction of dolphins in each stock that did not evade capture or was not "cut-out" (i.e., those chased and ultimately captured) as,

$$Fnot.cut_i = \frac{Ncap_i}{Nchase.with.set_i}.$$

We also estimated the "capture rate" for each stock as,

$$Fcap_i = \frac{Ncap_i}{Nchase.with.set_i + Nchase.without.set_i}.$$

In the first equation, 1-*Fnot.cut$_i$* would represent the efficiency of the fleet in cutting out individuals during a full purse-seine set operation. *Fcap$_i$* can be thought of as representing the probability that a dolphin involved in any chase will end up being captured.

Mean per capita chase and capture rates for northeastern offshore spotter and eastern spinner dolphins were calculated by dividing the estimates of annual number of dolphins chased or captured by the population sizes in each year estimated with a generalized logistic population model (Wade, 2002).

These estimates assumed that the observed sets and school sizes represented a random sample of all sets. Because the data for 1971-1985 came from U.S. vessels only, the assumption was that vessels of all fleets set on stocks in the same proportions as the U.S. fleet. Because different national fleets tend to operate in different areas, this assumption needed to be examined. We conducted a partial test of this assumption by comparing each of the ratios *nset$_i$/nset$_{total}$*, *ncap$_i$/nset$_{total}$*, and *nchase.with.set$_i$/nset$_{total}$* between NMFS and IATTC data during the period of overlap of the two datasets, 1986-1990, using paired *t*-tests.

RESULTS AND DISCUSSION

The estimated number of sets made on each stock from 1971 to 2000 is given in Table 3 and Figure 2. Figure 3 converts these numbers into percentages of sets involving each of the four stocks with the largest numbers of sets. Northeastern offshore spotted dolphins were the stock most frequently set on, being involved in about 60% of all dolphin sets, or approximately 4,000-6,000 sets/year in recent years. Western/southern offshore spotted dolphins and eastern spinners dolphins were approximately equal in the number of sets, with each occurring in 25%-30% of all dolphin sets, followed by whitebelly spinners with about 20%. Note that the sum of these percentages is > 100% because of mixed-species schools. All other stocks were present in fewer than 5% of the sets each on average. Table 4 and Figure 4 present the estimated number of dolphins captured per stock from 1977 to 2000. Figure 5 presents estimates of the mean number of captures per dolphin per year for the two main stocks affected by the fishery.

The estimated number of dolphins chased and set on from 1971 to 2000, and chased and not set on from 1975 to 2000 are given in Tables 5 and 6, respectively. Table 7 and Figure 6 give the estimated total number of dolphins chased per stock (i.e., the sum of values from Tables 5 and 6). Figure 7 presents our estimates of the average number of chases per dolphin per year for the two main stocks affected by the fishery..

Figures 8 present the fraction of dolphins not cut-out (retained) in chases that ended in a set. Eastern spinner dolphins either evade or are cut out of the chase more frequently than the other stocks (about 30% are captured in the net), while western/southern offshore spotted dolphins are infrequently cut out (80-90% are retained). Figure 9 presents the average "capture rate" for northeastern and western-southern spotted, and eastern and whitebelly spinner dolphins, given that a chase has begun. In recent years, when a chase begins for a northeastern offshore spotted dolphin, there is about a 40% chance that the dolphin will be encircled, while for eastern spinner dolphins, there is only about a 10% chance it will be encircled. Of course, these are average figures and do not account for many important factors that would affect the probability of capture, such as school size, location and weather.

The methodology of this analysis involved the allocation of unobserved or unknown data to stock using ratio estimators. The inherent assumption was that the true ratios in the unknown data were equivalent to those in the known data. We examined this briefly by conducting paired *t*-tests between NMFS and IATTC data for the five years of overlap (1986-1990). There were no significant differences between the two data sets for proportion of total sets, for average numbers of dolphins chased, or for average numbers captured per set. This suggests that had data from one of these sources been "unobserved", prorations using the other source would not have significantly changed the true allocations of sets or dolphins to stock. The ratio estimators also assumed that the observed number of sets, captures or chases was correlated with the observed number of sets on that stock. This seemed reasonable except possibly in the case of *Nchase.without.set$_i$*, where it remains to be demonstrated.

As the fraction of observed sets was quite small in the early '70s and '80s (Figure 1), any inaccuracies inherent in our proration scheme would have more of an effect on estimates from those years. During this time, most of the sets for which we did not have data did not carry observers. From 1992 to 1999, Mexico was the only non-U.S. national program in operation, with observers on approximately 50% of their trips. In 2000, Ecuador and Venezuela began sending observers, covering 3% and 35% of their trips respectively for that year. Since 1993, sampling coverage for the fleet capable of setting on dolphins has been at 100%, and every vessel carried either an IATTC observer or an observer from that country's national program.

The estimates presented in this report should be considered preliminary estimates that could be improved in several ways. In recent years, we could refine our estimates of the effect of the fishery if we obtained direct by-stock estimates of sets and numbers of dolphins chased and captured from the respective national program databases, similar to that provided by NMFS and IATTC. Further refinements on our estimates could probably be made by including such data as set location and tuna catch in the ratio estimators. This would be especially valuable in the earlier years, which rely more heavily on the NMFS data. Using data collected from 1979 to 1982, the IATTC presents evidence that there may have been a spatial or geographical bias in NMFS-observed trips relative to IATTC-observed trips (IATTC, 1985). Proration of unidentified spotted and spinner dolphins could be improved by utilizing set location.

Variances were underestimated for several reasons, and further work is needed. The bootstrap procedure treated N_{sets} and *nset$_{total}$* as fixed. Except in recent years with 100% observer coverage, N_{sets} was an estimate of the total number of dolphin sets and should therefore have a variance, although no measures of precision are given in the IATTC annual reports. Also, *nset$_{total}$* should be a random variable because sampling (observer

present) is actually done by trip, and trips have variable numbers of dolphin sets. In addition, we did not estimate variance for IATTC data except during 1996-2000. Further, variance of the number of dolphins chased did not include variance for *Nchase.without.set$_i$*.

For convenience, we have referred to the observer's school size estimates as the number of dolphins "chased". In an actual chase, the helicopter, seiner, and speedboats may attempt to "cut-out" a large part of the school prior to the net being set. Thus, part of the school (about 60% on average for northeastern spotted dolphins, 30% for eastern spinner dolphins: Figure 8) experiences the full chase and is subsequently captured, while the remainder of the school experience only part of the chase. Additionally, observer school size estimates have not been calibrated. While research vessel estimates are in general underestimates (Gerrodette et al 2002), tuna vessel estimates of school size are considerably larger, due in part to selection to set on larger schools (Perkins and Edwards 1998) and selective reporting of schools sighted (Lennert-Cody et al 2001).

A chase may be aborted at any time up to the point that the net skiff leaves the seiner to deploy the net around a school. With the data available to us, we were unable to determine the duration or extent of a chase in cases where no set was made. Additionally, because the time at which speedboats enter the water is traditionally used to identify the beginning of a chase, we potentially missed interactions of varying degrees between dolphins and the helicopter or seiner, as such data are usually not collected.

ACKNOWLEDGEMENTS

LITERATURE CITED

Dizon, A. E., W. F. Perrin, and P. A. Akin. 1994. Stocks of dolphins (*Stenella* spp. and *Delphinus delphis*) in the eastern tropical Pacific: a phylogeographic classification. NOAA Technical Report, National Marine Fisheries Service 119:1-20.

Gerrodette, T., Perryman, W., and J. Barlow. 2002. Calibrating group size estimates of dolphins in the eastern tropical Pacific Ocean. NMFS-SWFSC Administrative Report No. LJ-02-08. 27pp.

Inter-American Tropical Tuna Commission. 1999. Annual Report of the Inter-American Tropical Tuna Commission 2000. 310pp.

Inter-American Tropical Tuna Commission. 2002. Annual Report of the Inter-American Tropical Tuna Commission 2000. 171pp.

Lennert-Cody, C.E., S.T. Buckland, and F.F.C. Marques. 2001. Trends in dolphin abundance estimated from fisheries data: a cautionary note. Journal of Cetacean Research and Management 3(3):305-319.

Perkins, P.C. and Edwards, E.F. 1999. Capture rate as a function of school size in pantropical spotted dolphins, *Stenella attenuata*, in the eastern tropical Pacific Ocean. Fishery Bulletin (U.S.) 97(3):542-554.

Wade, P. R. 2002. Assessment of the population dynamics of the northeast offshore spotted and the eastern spinner dolphin populations through 2001. Southwest Fisheries Science Center, Administrative Report LJ-02-13.

Table 1. Number of dolphin sets made from 1971-2000. The right column includes sets without observers and national program-observed sets other than U.S.

Year	Total dolphin sets	Observed NMFS sets	Observed IATTC sets	National program and unobserved sets
1971	4,784	68	0	4,716
1972	8,084	276	0	7,808
1973	8,608	772	0	7,836
1974	7,759	1,133	0	6,626
1975	7,894	1,102	0	6,792
1976	7,084	1,298	0	5,786
1977	7,133	3,410	0	3,723
1978	5,098	1,780	0	3,318
1979	7,265	2,011	0	5,254
1980	6,456	1,049	0	5,407
1981	6,618	814	0	5,804
1982	4,940	860	0	4,080
1983	3,583	121	0	3,462
1984	5,928	388	0	5,540
1985	10,156	972	0	9,184
1986	8,843	634	2,623	5,586
1987	13,319	2,839	3,683	6,797
1988	11,200	1,006	3,307	6,887
1989	12,856	2,205	4,708	5,943
1990	11,026	845	4,854	5,327
1991	9,661	0	4,841	4,820
1992	10,423	0	6,725	3,698
1993	6,987	0	5,025	1,962
1994	7,807	0	5,350	2,457
1995	7,185	0	5,599	1,586
1996	7,474	0	5,844	1,630
1997	9,012	0	6,339	2,673
1998	10,645	0	8,018	2,627
1999	8,648	0	6,537	2,111
2000	9,235	0	6,087	3,148

Table 2. Definitions of dolphin stocks examined.

Stock / common name	Species	Notes*
Coastal spotted	*Stenella attenuata graffmani*	
Northeastern spotted	*Stenella attenuata attenuata*	North of 5°N and East of 120°W
Western-southern spotted	*Stenella attenuata attenuata*	South of 5°N or West of 120°W
Eastern spinner	*Stenella longirostris orientalis*	
Whitebelly spinner	*Stenella longirostris longirostris*	
Central American spinner	*Stenella longirostris centroamericana*	
Northern common	*Delphinus delphis*	North of 13-20°N
Central common	*Delphinus delphis*	Between 13-20°N and 3°N
Southern common	*Delphinus delphis*	South of 3°N
Other		Any identifiable cetacean not listed above

*see Dizon et al., 1994 for detailed descriptions

Table 3. Estimated number of sets made on dolphin stocks from 1971 to 2000. Values in parentheses are standard deviations from 1000 bootstrap replicates where available.

Year	Coastal spotted	Northeastern spotted	Western-southern spotted	Eastern spinner	Whitebelly spinner	Central American spinner	Northern common	Central common	Southern common	Other
1971	0	3,979 (215)	367 (164)	1,582	1,447	3	0	86	0	344
1972	0	5,312 (169)	271 (85)	1,753	1,895 (130)	3	0	708	0	153
1973	225 (43)	4,984 (111)	1,195 (54)	1,765 (100)	1,707 (96)	0	219	1,179	15	204
1974	8	5,505 (93)	916 (62)	1,891 (105)	1,362 (58)	0	0	977	8	392
1975	0	6,174 (90)	661 (74)	2,167 (114)	1,716 (96)	18 (12)	31	766	0	480
1976	0	3,217 (95)	3,337 (95)	1,685 (78)	2,391 (98)	11	17	477	6	236
1977	11 (4)	3,783 (63)	2,645 (61)	1,522 (52)	1,826 (54)	0	41	661	2	139
1978	0	2,377 (58)	2,687 (59)	965 (48)	1,826 (61)	0	21	99	9	135
1979	4 (4)	4,702 (76)	2,044 (72)	1,570 (66)	1,389 (63)	0	337	295	4	186
1980	0	4,558 (93)	1,853 (91)	1,377 (85)	1,480 (88)	0	89	38	0	102
1981	9 (8)	3,938 (116)	2,699 (115)	1,424 (96)	2,247 (114)	0	241	36	9	152
1982	6 (6)	3,175 (82)	1,915 (81)	1,143 (70)	1,324 (76)	0	0	141	0	134
1983	0	1,727 (155)	2,016 (159)	637 (118)	1,281 (150)	0	0	67	0	0
1984	0	3,224 (151)	3,099 (151)	1,952 (140)	1,802 (136)	0	0	35	0	121
1985	57 (23)	8,630 (123)	1,610 (108)	4,360 (163)	2,068 (122)	0	0	212	0	770
1986	17	5,561 (174)	2,420 (174)	2,744 (156)	2,099 (185)	0	227	312	14	239
1987	104 (9)	10,390 (98)	2,443 (89)	5,360 (127)	2,212 (87)	0	211	202	44	579
1988	71	7,614 (159)	2,389 (145)	3,847 (173)	1,513 (131)	6	226	516	126	337
1989	80	8,269 (130)	3,648 (128)	4,708 (135)	2,775 (124)	2 (6)	64	683	15	556
1990	110	7,283 (177)	3,185 (176)	2,954 (150)	2,937 (190)	0	68	221	4	326
1991	156	6,268	2,184	2,824	1,676	0	32	705	10	292
1992	299	7,784	1,242	2,877	1,147	0	150	663	3	284
1993	264	4,274	1,882	1,904	970	64	20	240	0	201
1994	65	4,467	2,763	2,283	1,635	6	20	267	4	240
1995	66	5,036	1,601	2,491	1,171	3	6	148	4	252
1996	42 (7)	5,516 (44)	1,615 (41)	2,397 (47)	1,094 (36)	29 (6)	19	67	1	188
1997	31 (6)	5,530 (54)	2,870 (51)	1,947 (46)	1,940 (48)	1 (1)	7	320	65	198
1998	239 (18)	5,888 (58)	2,913 (53)	3,069 (53)	1,489 (42)	28 (6)	317	633	53	160
1999	128 (13)	5,347 (51)	2,373 (46)	2,581 (48)	1,454 (40)	60 (9)	49	94	3	201
2000	94 (11)	4,243 (61)	3,454 (58)	1,889 (48)	1,664 (45)	42 (8)	59	943	32	173

Table 4. Estimated number of dolphins captured per stock from 1977 to 2000. Values in parentheses are standard deviations from 1000 bootstrap replicates where available.

Year	Coastal spotted	Northeastern spotted	Western-southern spotted	Eastern spinner	Whitebelly spinner	Central American spinner	Northern common	Central common	Southern common	Other
1977	4,655 (3,238)	2,086,939 (73,746)	2,354,022 (95,608)	158,147 (13,083)	328,816 (22,304)	0	22,718	82,017	347	7,189
1978	0	1,070,014 (59,247)	1,871,476 (88,529)	86,447 (11,259)	260,653 (20,406)	0	14,143	33,262	5,282	4,948
1979	1,815 (1,412)	1,769,109 (70,914)	1,157,762 (75,081)	116,048 (12,390)	174,789 (20,832)	0	92,855	84,079	370	9,974
1980	0	1,872,550 (97,346)	1,070,075 (92,748)	74,761 (11,473)	218,257 (33,777)	0	10,936	36,228	0	865
1981	0	1,085,289 (79,162)	1,506,060 (118,129)	81,713 (12,335)	326,638 (42,866)	0	96,083	9,997	4,544	791
1982	0	1,213,457 (79,561)	1,094,401 (87,631)	86,514 (15,011)	158,781 (22,838)	0	0	54,095	0	3,036
1983	0	389,484 (86,505)	1,332,724 (187,222)	47,317 (12,714)	188,693 (59,720)	0	0	4,985	0	0
1984	0	1,046,686 (107,632)	1,597,782 (145,994)	253,605 (42,610)	165,109 (24,806)	0	0	11,276	0	274
1985	1,357 (1,044)	2,806,884 (117,874)	787,570 (85,976)	468,758 (42,858)	336,284 (45,259)	0	0	118,488	0	3,290
1986	432	2,267,240 (192,931)	1,332,148 (152,099)	410,388 (44,037)	330,019 (68,401)	0	142,022	121,862	2,381	13,646
1987	2,701 (264)	3,239,095 (116,506)	1,389,558 (76,802)	595,328 (40,006)	281,602 (19,187)	0	69,148	116,625	42,663	7,140
1988	2,798	2,614,312 (148,742)	1,379,357 (124,351)	622,617 (57,549)	287,637 (32,692)	12,737	136,420	231,570	88,268	15,307
1989	13,843	3,203,302 (114,427)	2,864,263 (145,603)	632,991 (40,949)	559,572 (46,806)	1,167 (3,737)	11,779	425,500	10,885	12,279
1990	118,030 (1,495)	3,518,369 (238,880)	2,137,098 (149,583)	419,796 (41,347)	528,681 (50,522)	0	15,234	106,025	1,938	4,028
1991	592	2,317,471	1,181,143	482,300	297,914	0	194,304	163,907	3,258	18,215
1992	3,550	2,103,327	1,233,496	374,715	258,396	0	69,958	141,595	51,357	7,144
1993	2,306	1,567,410	832,404	393,560	182,358	10,496	106,607	154,703	72,737	10,710
1994	12,358	1,879,849	1,559,436	404,661	329,196	0	10,515	305,168	9,717	9,558
1995	90,373	2,227,800	1,390,433	297,449	345,687	0	11,687	79,773	1,486	2,650
1996	30,627 (5,351)	1,901,548 (37,108)	1,314,155 (37,854)	307,808 (10,413)	248,061 (10,553)	0	11,405	310,686	5,701	9,335
1997	40,504 (5,331)	2,244,851 (37,359)	747,655 (53,377)	274,454 (10,346)	166,544 (13,244)	0	20,202	379,932	2,001	8,440
1998	50,007 (7,305)	2,474,017 (29,526)	1,706,843 (37,978)	268,334 (18,860)	188,543 (12,970)	30,269 (4,858)	4,734	406,741	0	6,490
1999	38,338 (5,023)	1,511,085 (41,676)	2,222,821 (37,590)	293,889 (32,967)	257,379 (8,466)	2,962 (5,825)	8,560	170,871	432	4,029
2000	30,771 (5,697)	2,196,897 (37,747)	1,477,669 (52,489)	313,577 (10,600)	215,315 (10,531)	805 (877)	806	130,976	0	4,772

Table 5. Estimated number of dolphins chased and set-on per stock from 1971 to 2000. Values in parentheses are standard deviations from 1000 bootstrap replicates where available.

Year	Coastal spotted	Northeastern spotted	Western-southern spotted	Eastern spinner	Whitebelly spinner	Central American spinner
1971	0	946,169 (247,008)	305,383 (253,905)	307,797	340,227	1,342
1972	0	4,960,641 (526,929)	206,639 (443,143)	240,813	287,507 (188,110)	1,045
1973	552,353 (168,401)	4,223,837 (538,579)	569,860 (156,683)	122,192 (201,510)	34,904 (130,658)	135,145
1974	0	4,454,556 (245,572)	596,081 (110,573)	1,120,293 (157,710)	143,874 (64,784)	59,155
1975	0	6,531,495 (268,171)	648,214 (133,464)	1,151,791 (167,473)	375,364 (91,476)	195,538 (21,019)
1976	0	3,091,312 (194,347)	3,807,609 (228,447)	615,094 (125,601)	879,425 (128,070)	420,454
1977	14,473 (9,853)	3,637,470 (123,512)	3,773,317 (143,497)	547,216 (35,422)	627,346 (39,000)	0
1978	0	2,147,564 (100,976)	2,907,517 (127,517)	314,126 (31,085)	497,919 (35,656)	0
1979	1,916 (1,825)	2,758,062 (93,339)	1,438,023 (84,077)	330,572 (26,597)	232,971 (22,539)	0
1980	0	3,050,554 (164,567)	1,256,483 (98,788)	314,448 (48,552)	289,023 (36,865)	0
1981	2,598 (2,419)	1,802,733 (110,273)	2,004,700 (142,691)	285,216 (36,188)	425,398 (45,090)	0
1982	121 (116)	1,850,884 (103,082)	1,359,642 (100,679)	294,850 (37,934)	230,375 (26,338)	0
1983	0	566,948 (95,514)	1,519,771 (223,202)	116,803 (37,433)	264,071 (63,377)	0
1984	0	1,515,121 (132,617)	1,855,524 (160,783)	402,084 (53,410)	205,276 (27,725)	0
1985	19,169 (12,267)	4,463,947 (185,078)	1,134,463 (115,560)	1,297,058 (93,515)	683,465 (79,881)	0
1986	2,064	3,423,244 (244,299)	1,599,289 (171,335)	1,058,023 (146,477)	526,605 (80,007)	0
1987	50,601 (45,103)	5,705,100 (178,208)	1,758,133 (89,410)	1,861,817 (101,787)	476,014 (29,063)	0
1988	21,030	4,279,062 (198,582)	1,768,756 (146,560)	1,773,754 (120,275)	395,405 (35,531)	28,348
1989	34,309	5,340,616 (178,839)	3,317,433 (160,364)	2,047,461 (108,086)	788,804 (54,923)	4,579 (14,301)
1990	154,384	4,871,710 (265,761)	2,463,733 (175,338)	1,138,699 (104,237)	764,161 (77,758)	0
1991	2,801	3,641,964	1,417,661	1,264,592	501,077	0
1992	37,316	3,770,210	1,548,001	1,158,548	418,872	0
1993	17,050	2,636,544	1,084,905	1,151,526	247,783	22,983
1994	30,558	3,231,225	1,848,701	1,309,533	475,406	0
1995	117,952	3,127,107	1,586,521	797,188	486,412	0
1996	99,338 (13,199)	3,044,200 (53,373)	1,475,734 (41,045)	863,642 (42,443)	333,217 (13,390)	0
1997	154,915 (9,577)	3,761,601 (55,792)	837,075 (60,705)	894,032 (47,526)	276,822 (38,783)	0
1998	239,482 (26,133)	4,223,380 (40,334)	1,965,071 (43,602)	1,212,480 (52,340)	386,079 (20,142)	381,586 (12,057)
1999	86,762 (17,073)	2,726,238 (55,394)	2,443,037 (43,933)	1,146,436 (87,748)	494,748 (17,053)	38,195 (34,500)
2000	132,012 (17,501)	3,553,552 (52,082)	1,730,197 (67,849)	1,383,477 (55,922)	398,378 (24,181)	6,738 (16,496)

Table 5 (cont.). Estimated number of dolphins chased and set-on per stock from 1971 to 2000.

Year	Northern common	Central common	Southern common	Other
1971	1,342	407,897	0	34,792
1972	1,045	576,239	0	0
1973	402,496	1,120,210	0	2,077
1974	0	1,946,415	262	41,705
1975	30,485	855,298	0	42,408
1976	42,305	924,761	2,042	18,352
1977	114,762	1,008,959	430	21,923
1978	50,084	162,870	4,185	20,439
1979	302,957	407,650	2,191	17,355
1980	78,794	43,264	0	1,983
1981	269,697	23,557	4,841	5,520
1982	0	125,553	0	13,141
1983	0	20,561	0	0
1984	0	23,920	0	1,555
1985	0	338,465	0	11,441
1986	325,364	330,339	4,152	16,327
1987	319,728	203,360	50,732	26,330
1988	362,244	645,572	85,222	45,156
1989	27,926	891,742	9,007	26,438
1990	62,412	311,045	3,782	14,905
1991	441,650	444,499	5,636	20,567
1992	319,813	235,045	51,883	19,527
1993	281,227	428,830	69,092	34,943
1994	24,873	655,108	8,023	20,404
1995	47,684	233,655	2,890	10,510
1996	24,455	781,399	13,375	21,317
1997	57,821	688,887	1,874	15,278
1998	10,394	672,270	0	29,483
1999	12,743	355,426	1,528	11,034
2000	1,447	242,953	1,641	11,630

Table 6. Estimated number of dolphins chased and not set-on per stock from 1975-2000.

Year	Coastal spotted	Northeastern spotted	Western-southern spotted	Eastern spinner	Whitebelly spinner	Central American spinner	Northern common	Central common	Southern common	Other
1975	0	3,728,854	274,655	900,123	35,118	48,311	1,827,349	39,473	0	212,013
1976	0	2,485,213	1,418,521	522,099	565,271	592,098	632,817	84,085	135,584	411,404
1977	0	2,004,397	1,494,117	1,389,616	748,924	0	541,853	162,550	39,387	268,295
1978	0	1,768,797	1,300,584	629,415	582,369	24,384	119,513	113,366	27,675	304,146
1979	0	1,933,810	454,504	729,461	315,715	0	362,218	181,293	26,849	180,294
1980	3,967	1,950,968	619,980	705,173	383,169	0	49,061	119,204	13,479	30,815
1981	0	1,288,472	661,733	646,454	412,757	0	39,576	5,823	223	167,198
1982	0	1,303,987	507,375	389,369	239,908	0	137,883	11,147	10,683	115,890
1983	0	463,653	368,277	241,673	129,547	0	63,690	195,953	0	61,458
1984	0	1,109,358	1,336,021	1,031,973	372,093	0	38,859	0	0	103,909
1985	0	2,657,185	700,303	1,806,861	460,965	0	130,542	0	0	30,836
1986	5,099	2,501,539	1,268,185	1,188,230	442,785	0	315,499	311,314	5,388	62,687
1987	32,448	4,423,773	880,433	2,037,004	549,574	0	205,301	256,780	9,704	81,858
1988	26,054	3,054,162	782,085	1,674,593	256,599	20,143	440,449	311,714	40,626	132,969
1989	117,673	4,372,296	1,693,900	2,480,249	734,882	0	470,705	31,269	40,069	88,650
1990	51,250	3,363,733	1,254,146	1,438,928	743,443	0	185,075	42,255	11,440	71,602
1991	7,218	2,986,152	1,155,372	1,398,896	439,747	0	422,151	440,674	7,627	80,431
1992	27,294	3,058,496	739,955	1,341,614	500,521	0	150,623	231,484	13,879	89,787
1993	20,552	1,926,959	501,878	1,027,830	169,679	0	288,291	245,885	32,046	92,938
1994	107,720	2,688,806	892,903	1,559,725	407,261	0	319,909	27,919	29,700	44,888
1995	38,691	2,257,166	799,080	907,059	448,988	0	90,632	31,900	8,637	38,658
1996	54,063	2,369,560	974,283	923,480	327,440	0	386,616	26,142	27,959	79,740
1997	55,996	2,859,074	746,743	811,476	341,579	0	464,550	58,182	0	45,549
1998	252,215	4,030,202	1,139,587	1,473,420	423,976	28,923	381,321	27,439	0	46,630
1999	32,175	2,543,036	1,301,050	1,198,403	567,477	1,286	231,046	52,370	23,056	34,910
2000	110,369	3,260,140	1,044,611	1,064,484	440,979	3,010	199,443	1,501	16,837	30,187

Table 7. Total estimated number of dolphins chased per stock from 1975-2000.

| Year	Coastal spotted	Northeastern spotted	Western-southern spotted	Eastern spinner	Whitebelly spinner	Central American spinner	Northern common	Central common	Southern common	Other
1975	0	10,260,350	922,869	2,051,915	410,482	243,849	69,958	2,682,646	0	254,422
1976	0	5,576,525	5,226,129	1,137,193	1,444,696	1,012,552	126,390	1,557,578	137,626	429,756
1977	14,473	5,641,867	5,267,434	1,936,832	1,376,270	0	277,312	1,550,812	39,817	290,219
1978	0	3,916,360	4,208,101	943,541	1,080,288	24,384	163,451	282,383	31,861	324,585
1979	1,916	4,691,872	1,892,526	1,060,033	548,686	0	484,250	769,868	29,040	197,649
1980	3,967	5,001,522	1,876,464	1,019,621	672,192	0	197,999	92,325	13,479	32,798
1981	2,598	3,091,205	2,666,433	931,670	838,155	0	275,520	63,133	5,064	172,718
1982	121	3,154,871	1,867,017	684,219	470,283	0	11,147	263,436	10,683	129,031
1983	0	1,030,601	1,888,048	358,476	393,618	0	195,953	84,251	0	61,458
1984	0	2,624,479	3,191,545	1,434,057	577,369	0	0	62,779	0	105,464
1985	19,169	7,121,132	1,834,766	3,103,918	1,144,430	0	0	469,007	0	42,277
1986	7,163	5,924,783	2,867,475	2,246,253	969,390	0	636,678	645,838	9,540	79,014
1987	83,049	10,128,873	2,638,566	3,898,820	1,025,589	0	576,508	408,661	60,436	108,188
1988	47,084	7,333,223	2,550,841	3,448,348	652,003	48,491	673,957	1,086,021	125,848	178,126
1989	151,982	9,712,911	5,011,333	4,527,710	1,523,687	4,579	59,195	1,362,447	49,077	115,088
1990	205,635	8,235,443	3,717,880	2,577,626	1,507,603	0	104,666	496,120	15,222	86,506
1991	10,020	6,628,116	2,573,032	2,663,488	940,824	0	882,324	866,650	13,263	100,998
1992	64,610	6,828,706	2,287,955	2,500,162	919,393	0	551,297	385,668	65,762	109,314
1993	37,602	4,563,503	1,586,783	2,179,356	417,462	22,983	527,112	717,121	101,138	127,881
1994	138,278	5,920,031	2,741,605	2,869,259	882,667	0	52,792	975,017	37,723	65,292
1995	156,643	5,384,272	2,385,601	1,704,247	935,400	0	79,584	324,287	11,526	49,168
1996	153,401	5,413,761	2,450,017	1,787,122	660,658	0	50,597	1,168,015	41,335	101,057
1997	210,911	6,620,675	1,583,818	1,705,508	618,401	0	116,003	1,153,437	1,874	60,827
1998	491,697	8,253,582	3,104,658	2,685,900	810,055	410,510	37,834	1,053,591	0	76,114
1999	118,937	5,269,274	3,744,087	2,344,838	1,062,225	39,481	65,112	586,472	24,584	45,944
2000	242,382	6,813,692	2,774,808	2,447,960	839,357	9,748	2,948	442,396	18,478	41,817
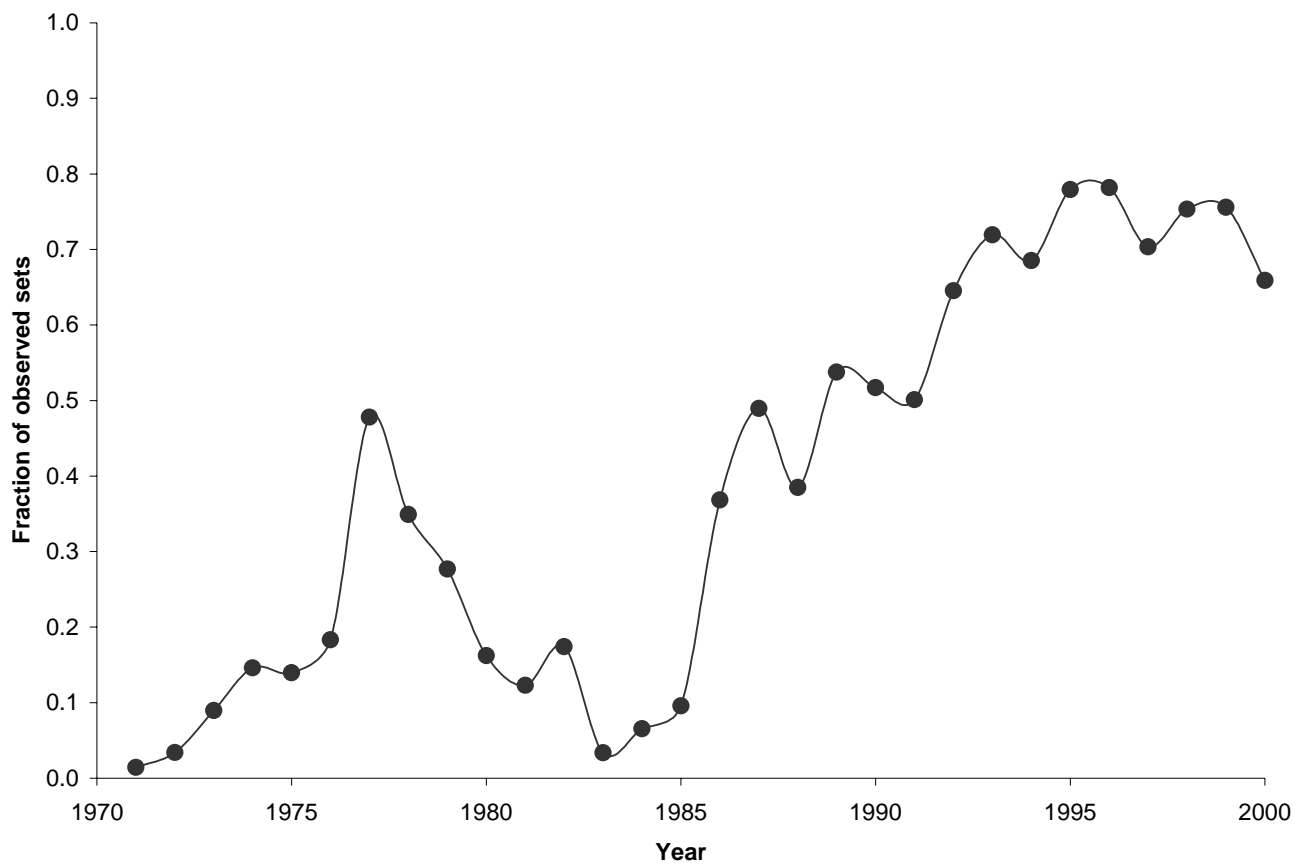
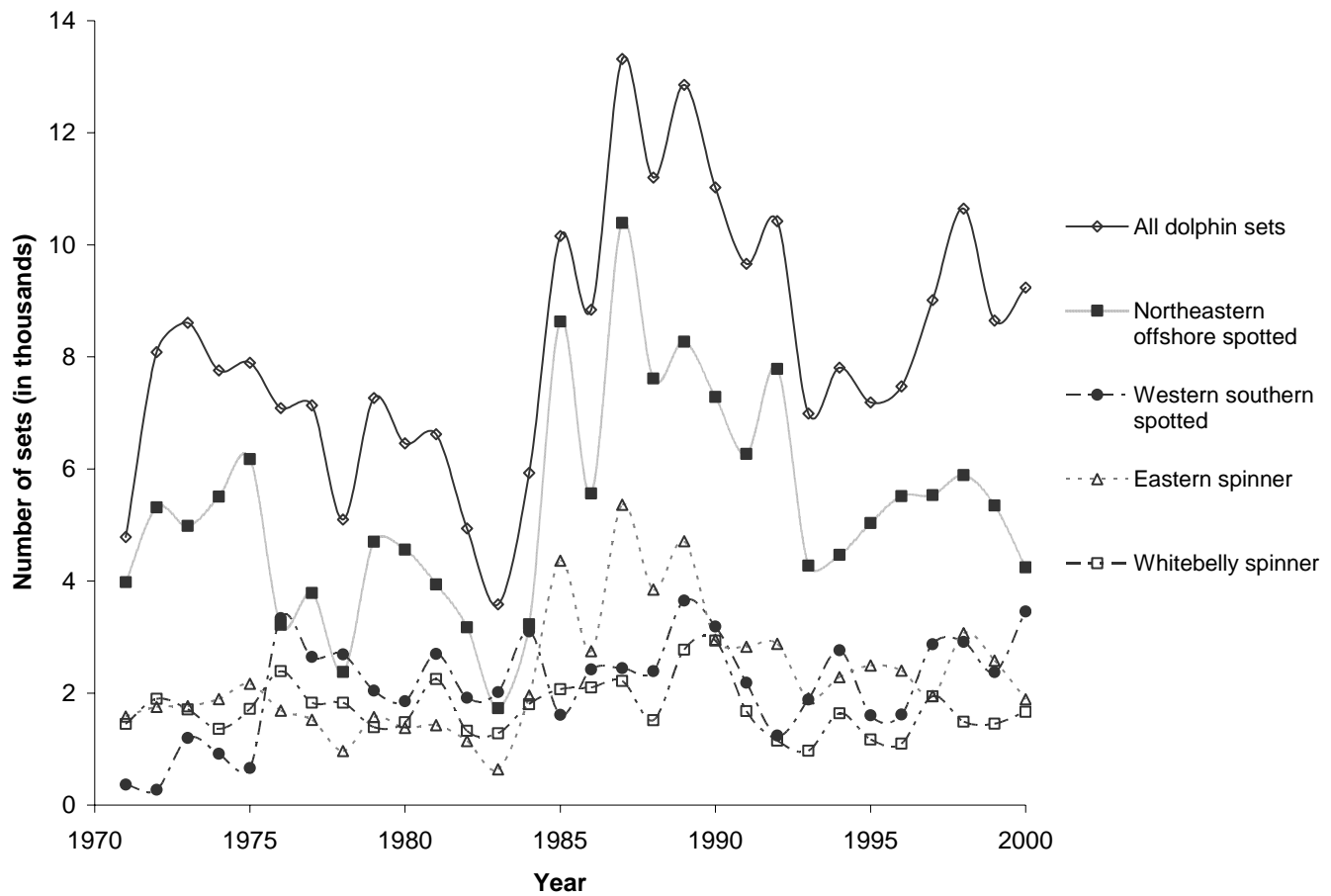Figure 1. Fraction of all dolphin sets with NMFS and IATTC observers from 1971 to 2000.

Figure 2. Annual number of dolphin sets (from IATTC Annual Reports), estimated number of sets on northeastern and western-southern offshore and spotted dolphins, and eastern and whitebelly spinner dolphins (1971-2000).
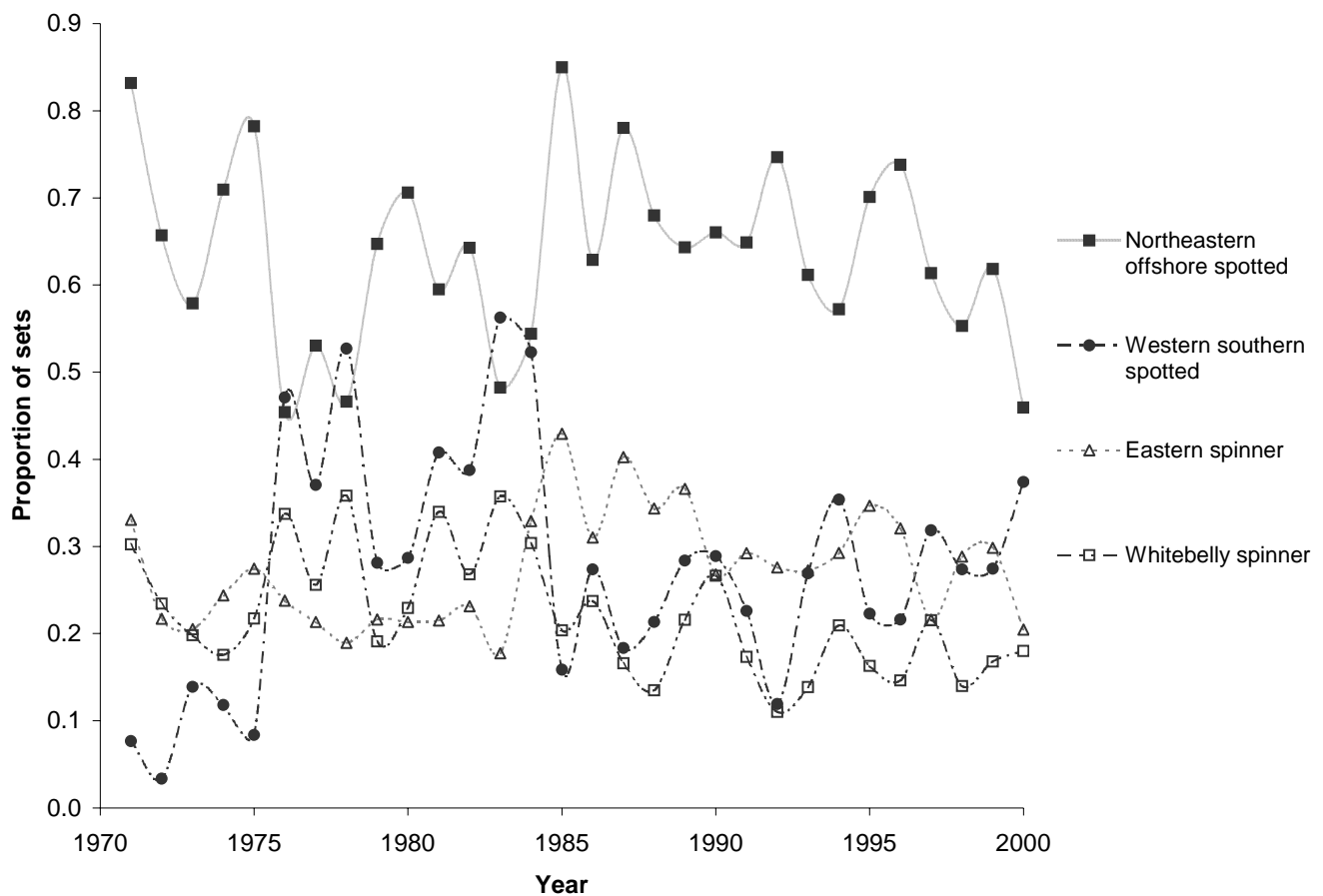
Figure 3. Annual proportion of dolphin sets which involve northeastern and western-southern offshore and spotted dolphins, and eastern and whitebelly spinner dolphins (1971-2000). The proportions in each year sum to more than 1.0 because of mixed-species schools.
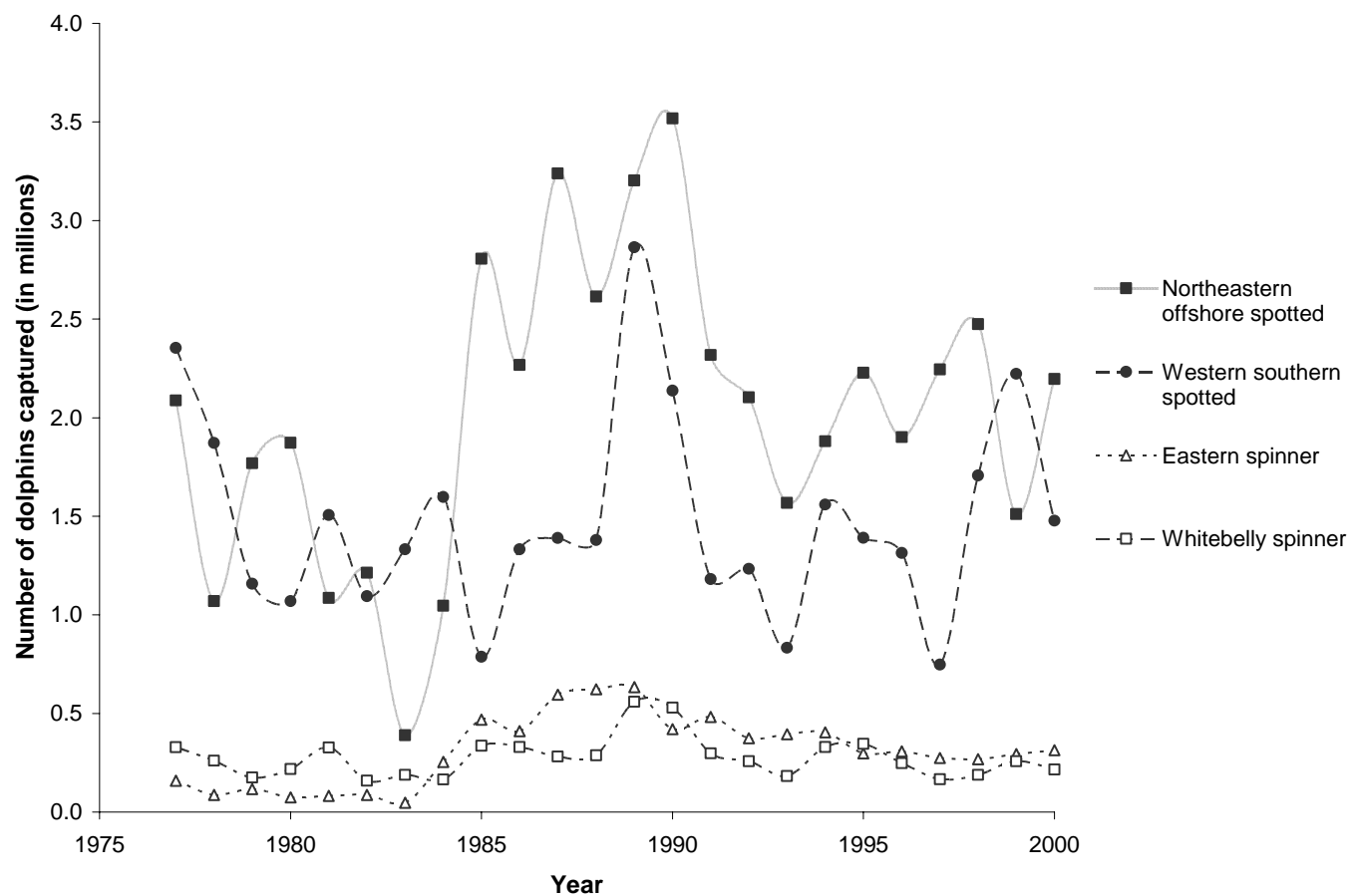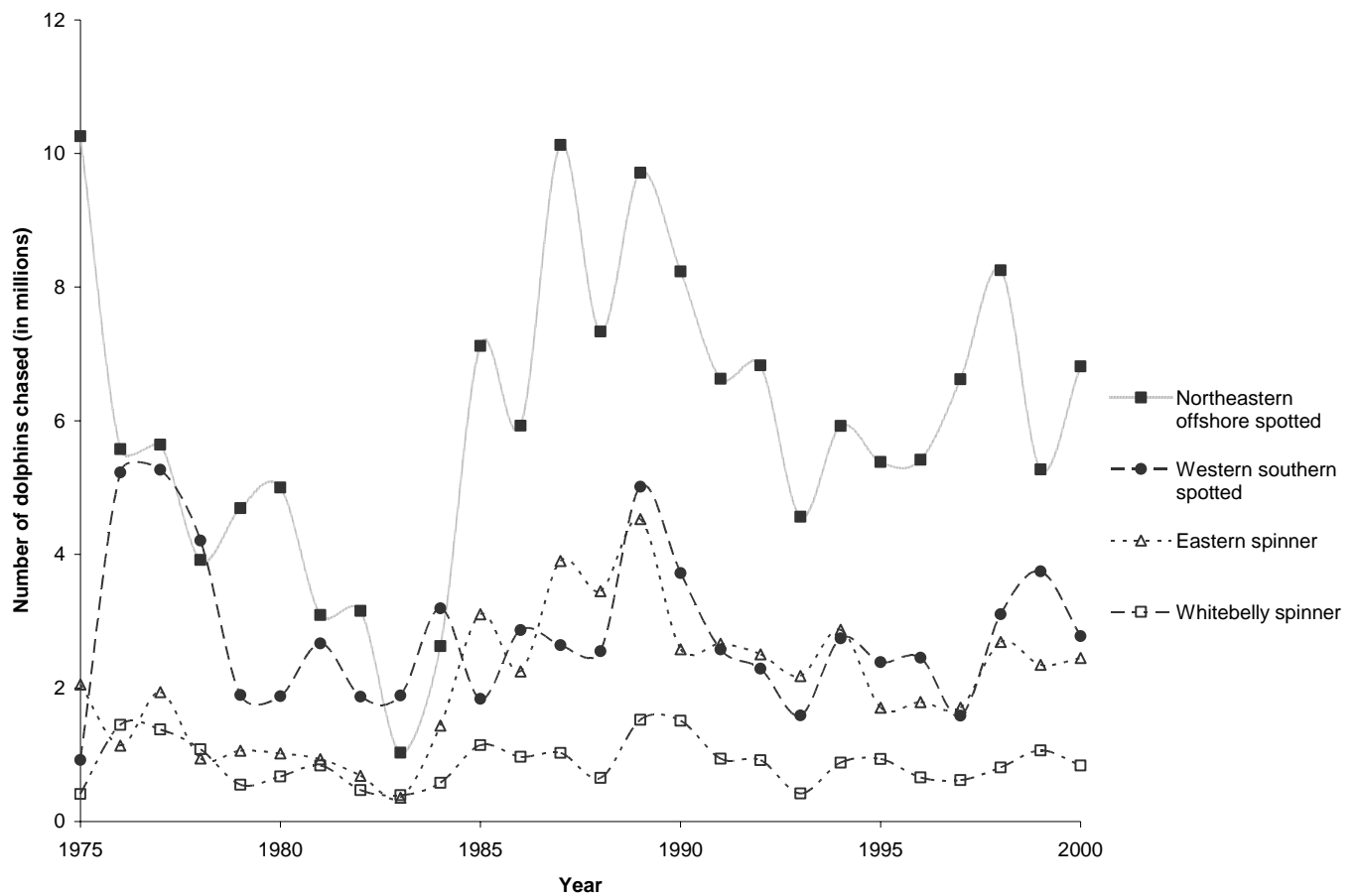
Figure 4. Annual number of dolphins captured for northeastern and western-southern
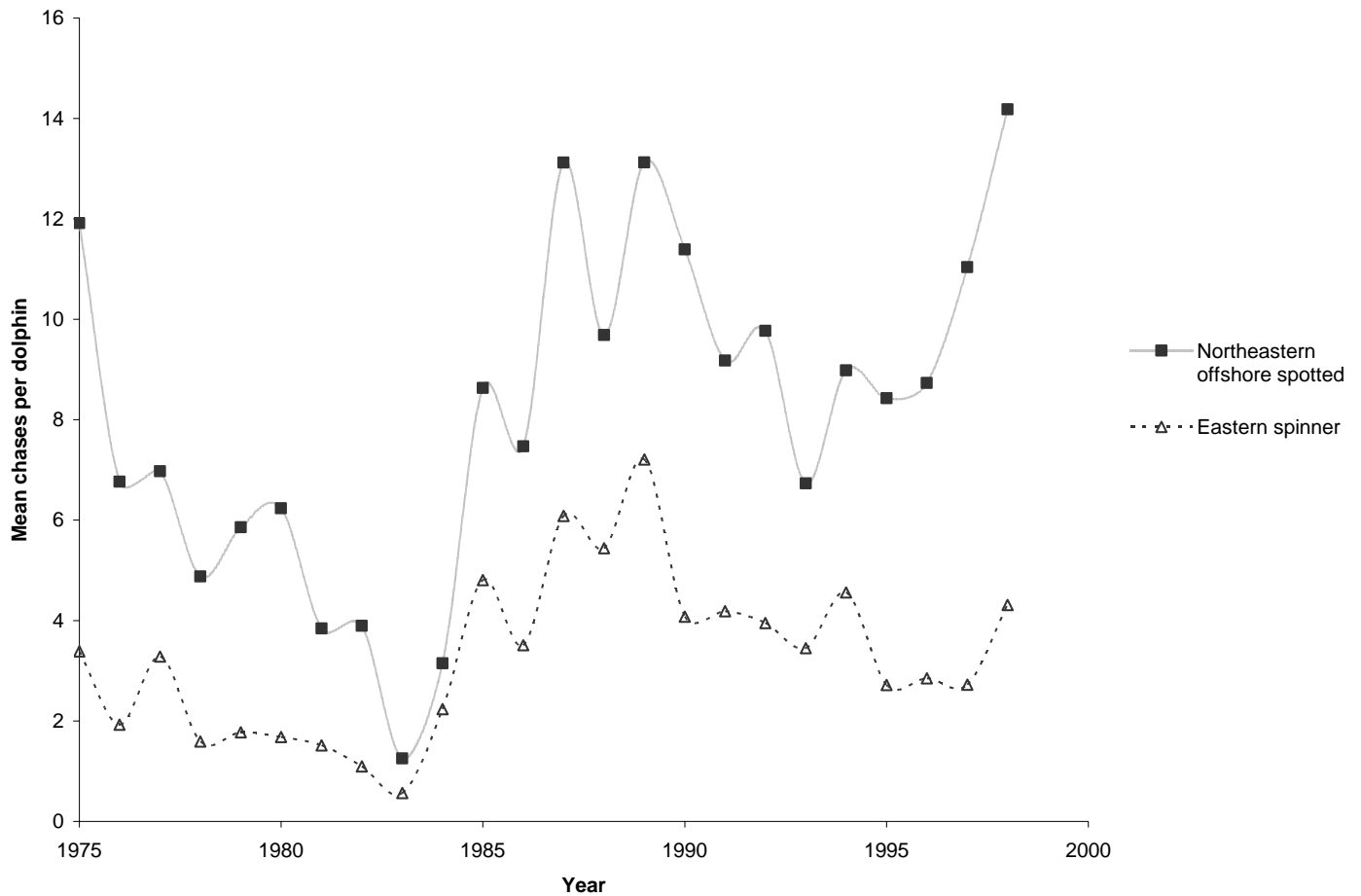offshore spotted, and eastern and whitebelly spinners (1977-2000).
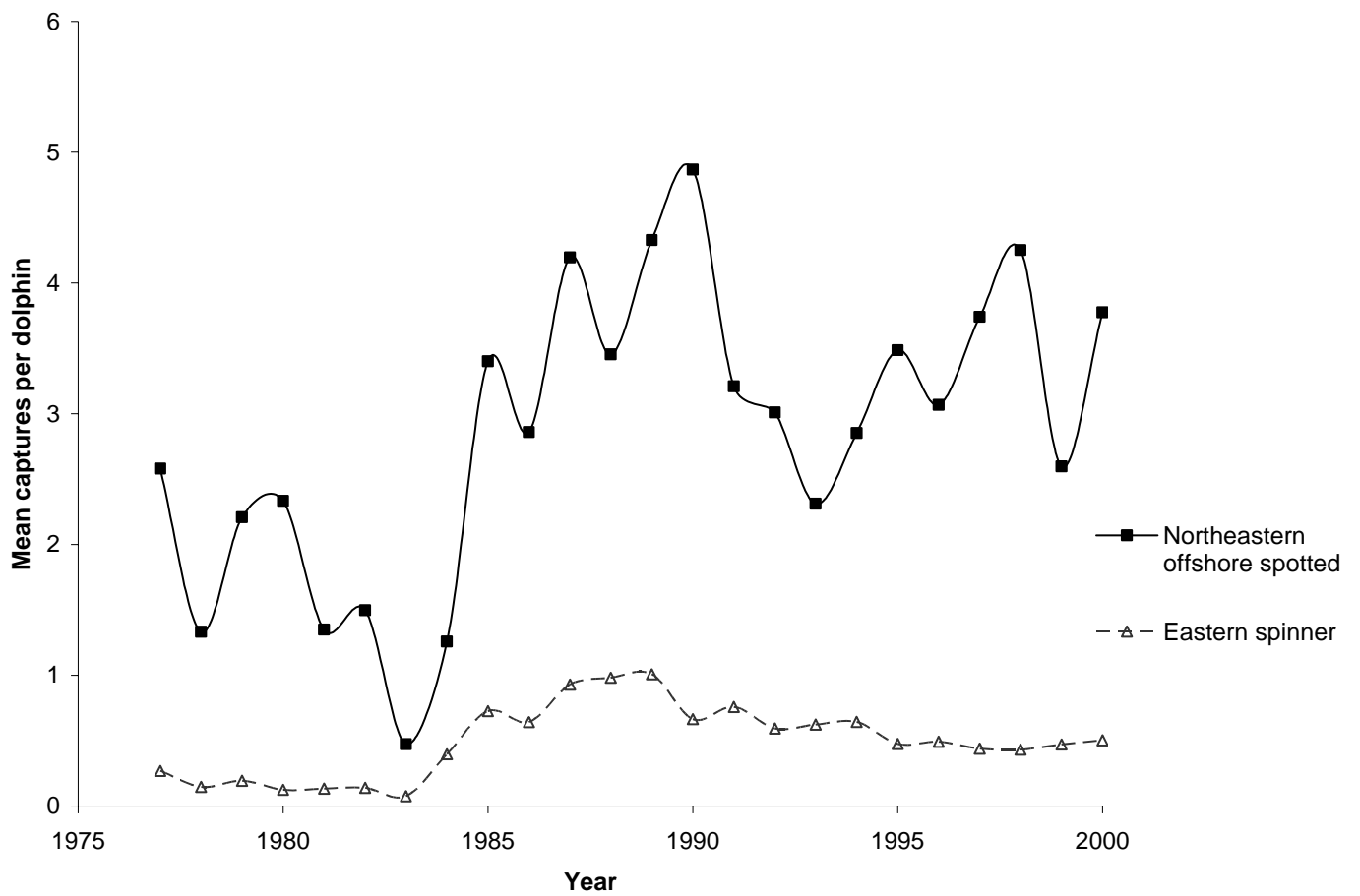
Figure 5. Mean number of captures per dolphin annually for northeastern spotted and eastern spinner dolphins (1977-2000).

Figure 6. Annual number of dolphins chased for northeastern and western-southern offshore spotted, and eastern and whitebelly spinners (1975-2000).

Figure 7. Mean number of chases per dolphin annually for northeastern spotted and eastern spinner dolphins (1975-2000).
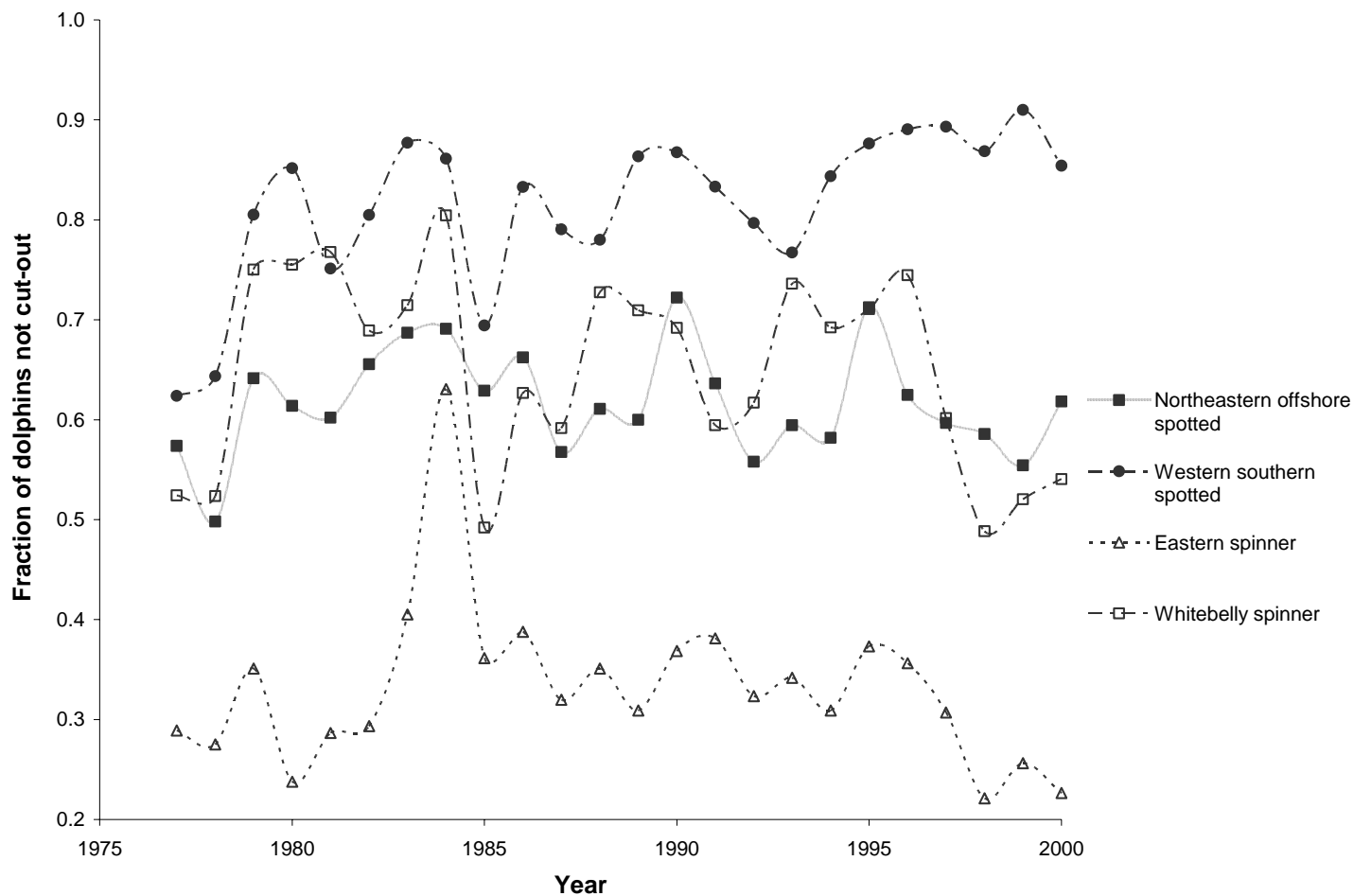
Figure 8. Fraction of dolphins retained (not cut-out) annually in completed sets (1977-2000).
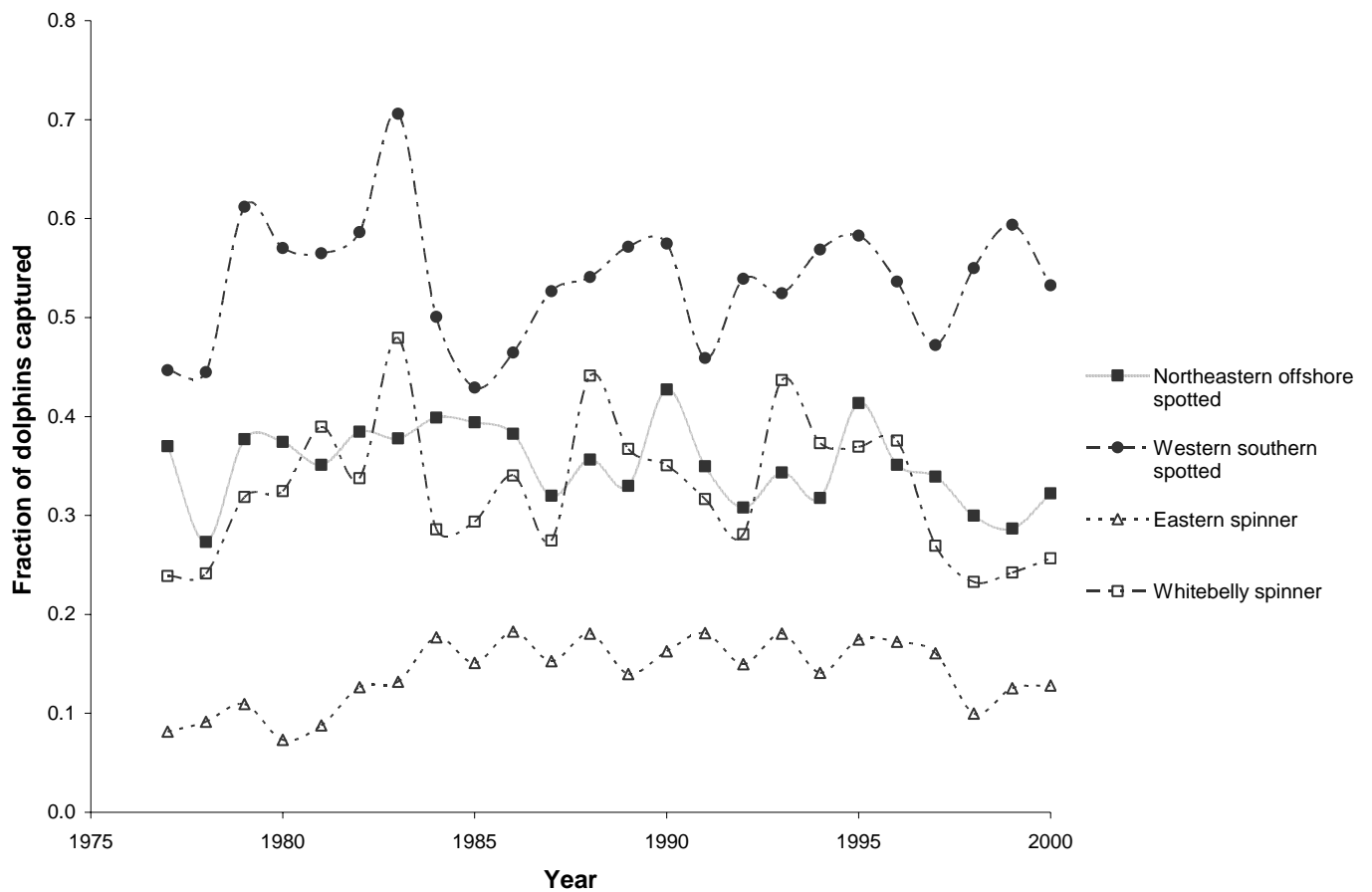
Figure 9. Fraction of dolphins captured annually relative to total number chased (1977-2000).